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Job Performance Report
Project F-73-R15

HATCHERY TROUT EVALUATIONS

Subproject V, Study I

Job 1. Synopsis of Information and Guidelines for Management of Put-and-Take Trout in Streams

Job 2. Persistence and Dispersion of Put-and-Take Trout in Streams

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ABSTRACT

This report provides an analysis of existing information concerning management of put-and-take trout in streams. Guidelines for the use of hatchery fish can be used to modify programs to improve cost effectiveness and angler harvest.

Several interrelated factors increase angler success and reduce costs of put-and-take programs. Most important of these are angling effort, stocking rate, and catchability of stocked fish.

Hatchery-reared trout rarely survive as well as wild fish in streams. Immediate and heavy fishing pressure is necessary to recover large percentages of fish stocked. Stocking should match effort where catch and return rate goals are similar. In order for pressure to be effective, fish must be catchable.

At any given water with a stable stocking program, catchability is primarily dependent on the fish and the environment they are released into. Careful attention to fish stock or strain, health, size, and stocking site should produce better fishing.

Evaluation of put-and-take fisheries is necessary to maintain fishing quality. Evaluation means angler use and harvest surveys (structured creel census), as well as more frequent site-specific monitoring of use or catchability.

If better returns, more participation and a satisfied fishing public are desired, we also need to make sure people know exactly where hatchery fish can be caught, and consistently provide that opportunity. Stocking publicity and improved hatchery trout management should be cost-effective.

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INTRODUCTION

Resource agencies stock trout literally by the ton to provide millions of hours of recreation in put-and-take fisheries nationwide. These programs amount to big business; they have staggering economic impact (Hartzler 1988). Since harvest is the intended result of most hatchery trout programs, agencies must stock enough fish to provide acceptable angler success. Stocking is expensive; hatchery rearing takes time, material, and manpower. Adequate returns are necessary to justify expenditure of limited license dollars.

The State of Idaho stocks streams with 564,500 put-and-take trout annually at a cost of $350,000. This amounts to $0.62 per fish, $3,500 per stream stocked, and 1.4 trout per licensed angler (Reid 1989). Despite these expenditures we have evaluated less than 2% of the stream stocking program annually with systematic creel census over the last 37 years. Most Idaho evaluations of hatchery trout have in fact been incidental to wild trout assessments.

The goal for Idaho's put-and-take stocking program is 40% or better return-to-creel. The 1991-1995 Fisheries Management Plan calls for discontinuation of put-and-take programs where significantly lower returns can not be improved (IDFG 1991). Return rates of put-and-take trout in Idaho streams have averaged 33% (IDFG progress reports). Each fish harvested, therefore, cost Idaho anglers $1.88 at present expenditures (IDFG 1991).

To improve management of hatchery fish, the Idaho Department of Fish and Game (IDFG) initiated a hatchery trout evaluation in 1991. Mauser (1992) summarized preliminary stocking relations and size experiments for put-and-take rainbow trout *Oncorhynchus mykiss* in Idaho streams. This Job (1) summarizes both primary and grey literature on put-and-take trout management in streams, including persistence and dispersion experiments reported here (Job 2).

OBJECTIVES

1. Develop a nationwide perspective that provides guidance for the put-and-take stocking program in Idaho streams.

2. Develop guidelines for the use of put-and-take trout in Idaho streams.

METHODS

I reviewed published literature and agency reports for information on put-and-take trout management. I summarized concepts relevant to program improvement. Specifically, I sought information on the effect of stocking rate, angling and management effort, and fish behavior on catch and return rates.

I incorporated results of hatchery trout persistence and movement (Job 2) and size experiments (Mauser 1992) in synopsis and guidelines.

RESULTS AND DISCUSSION

Program Goals

The purpose of put-and-take trout stocking is to "make fishing" (Butler and Borgeson 1965). Most programs are successful in this regard because stocking attracts fishermen. Besides participation, the primary component of put-and-take programs is catching fish to keep and eat (Hartzler 1988).

Agency goals for angler success are generally expressed as catch or harvest rates (fish/hour). Put-and-take trout management involves intensive stocking to provide high consumptive catch rates (IDFG 1991). Harvest rates can be much lower than catch rates; both are limited by the amount of fishing pressure on a body of water (Turner 1983).

New York considered a mean catch rate of 0.5 fish/h and harvest of 25 g/h minimum for high quality stream fisheries (Engstrom-Heg 1990). McMichael and Kaya (1991) found catch rates of 0.4-0.7 fish/h minimum for angler satisfaction on sections of the Madison River, Montana. Trout management goals for lakes of the Black Hills of South Dakota called for an average catch rate of 0.5 fish/h and a minimum return-to-creel of 75% of the fish stocked (Lyons 1964).

Catch rates greater than 0.5 fish/h often **are** considered to be good fishing (Turner 1983). Where catch rate goals are stated for put-and-take stream fisheries in Idaho, they range from 0.25-1.0 fish/h (IDFG 1991). I recommend minimum harvest rates of 0.5 fish/h to maintain angler interest on streams managed as high-yield put-and-take fisheries.

Hatchery trout management in Idaho is designed to provide angling opportunity to the general public (IDFG 1991). Program direction for 1990-95 is to increase emphasis on hatchery trout programs by improving efficiency rather than by increasing production. Fishing opportunity will be increased by:

1. Concentrating releases of put-and-take fish in easily accessible, heavily-fished waters;

2. Timing releases to coincide with peaks in fishing pressure;

3. Testing strains of rainbow trout which improve returns to creel;

4. Publicizing the location of put-and-take streams;

5. Improving pools and holding water where possible; and

6. Producing a consistently high-quality product.

Several interrelated factors can increase angler success and program effectiveness. The most important of these are angling effort (f), catchability of the fish (q), and stocking (N). Informed manipulation of these variables can partially offset constraints imposed on hatchery trout management by natural conditions.

Program Limitations

Limited survival is key to understanding stocking programs. Most investigators have concluded that put-and-take trout die relatively soon after stocking in streams. Where fishing intensity is high, harvest accounts for most of the mortality (Butler and Borgeson 1965). Fish that are not caught soon after stocking can still be lost to direct human benefit due to high mortality rates. After a century of stocking we do not know exactly how or why heavy post-stocking mortality occurs, but it is quite universal (Hartzler 1988). Stress associated with handling and stocking, and maladaptive behavior exhibited by hatchery fish in streams are factors fishery workers continue to examine (Hanson and Margenau 1992; Wiley et al 1993).

One view of post-stocking mortality assumes hatchery rearing merely prolongs the survival of fish that would normally die at an early age in a natural environment (Hartzler 1988). Miller (1953) suggested the effect of the hatchery is to delay rigorous natural selection which prevails in nature. We should, therefore, expect a fairly high rate of mortality for stocked fish. Trout which have been selected for many generations to perform well under hatchery conditions will not maintain characteristics of behavior, physiology, and anatomy adequate to enable them to survive at the same rate as wild fish (Cooper 1959).

Annual losses of 50% or more are normal for wild trout populations. Each year 13-86% of stream-resident trout die (McFadden 1969). Most of this mortality is unexplained (Turner 1983). Estimates of natural mortality in Idaho streams range from 31-64% (Schill 1991). Given losses of this magnitude for wild fish, it is not surprising that hatchery trout survival is low.

Researchers have described many differences in wild and hatchery fish (Hochachka 1961; Jenkins 1971; Reisenbichler and McIntyre 1977; Ersbak and Haase 1983; Bachman 1984; Suboski and Templeton 1989; Mesa 1991). Most have reinforced Cooper's (1959) thesis that we should not expect hatchery fish to survive at or near wild trout rates.

Since hatchery-reared trout generally do not survive for long periods of time in streams, Cooper (1959) considered immediate and heavy fishing pressure the only way to recover **a** large percentage of stocked fish.

Angling and Management Effort

Fishing Pressure

Harvest of put-and-take trout is determined primarily by angling effort (Cooper 1959; Bjornn 1960; Hammond and Lackey 1976; Hartzler 1988; Wiley et al 1993a). Low effort results in low returns because hatchery fish do not usually survive long enough to sustain a cumulatively high harvest (Wiley et al 1993b). Increasing effort increases return rates (Corley 1966; Thurow 1990), but will decrease angler success or rate of catch (Ratledge 1966; Rohrer 1991; Smith 1991; Mauser 1992). High catch rate and return goals are, therefore, often not mutually attainable (Lyons 1964; Kelly 1965).

Fishing pressure on any body of water can vary dramatically over time. However, the timing of cumulative angling effort can be remarkably similar, even for different waters and years (Job 2, Appendices D-F). To correspond with fishing effort on most Idaho streams, about 75% of the fish should be distributed before August 1.

Butler and Borgeson (1965), and Moring (1985) demonstrated that effort can depend on stocking rate, though exceptions often occur (Cuplin 1959; Kelly 1965). Fishing effort (f), stocking (N), return, and catch rate (c/f) are related by the equation (Lyons 1964; Kelly 1965).

$$N = (c/f)f/R \qquad (1)$$

Where fishing effort is known, the relationship can be useful to determine annual allocations, or stocking densities (fish/hectare/year). Where evaluations have been conducted, Idaho streams have supported an average of roughly 330 hours/hectare/year (IDFG progress reports). At mean catch rates of 0.5 fish/h and 40% return the relationship calls for stocking about 400 fish/hectare/year for 330 h/hectare (Figure 1).

Management Effort

Trout are often caught within a few weeks of stocking in put-and-take fisheries (Richards 1960; Butler and Borgeson 1965; Spence 1971; North 1983; Chapman 1983; Rohrer 1990). Efficient hatchery programs depend on angler participation. Catch rates and fish quality should be adequate to maintain angler interest. Fishery workers need to monitor put-and-take fisheries closely and adjust stocking frequency often to ensure consistently good fishing. Assessment (angler use and harvest surveys) should be considered pre-requisite to high-yield put-and-take fisheries (Hartzler 1988).

Many authors have identified stocking evaluations as key to successful hatchery programs. Evaluation is necessary to avoid wasting both time and fish, and to maintain good fishing (Hartzler 1988). Stocking programs need to be well documented to allow assessment and improved management (Hilborn 1992). Stocking

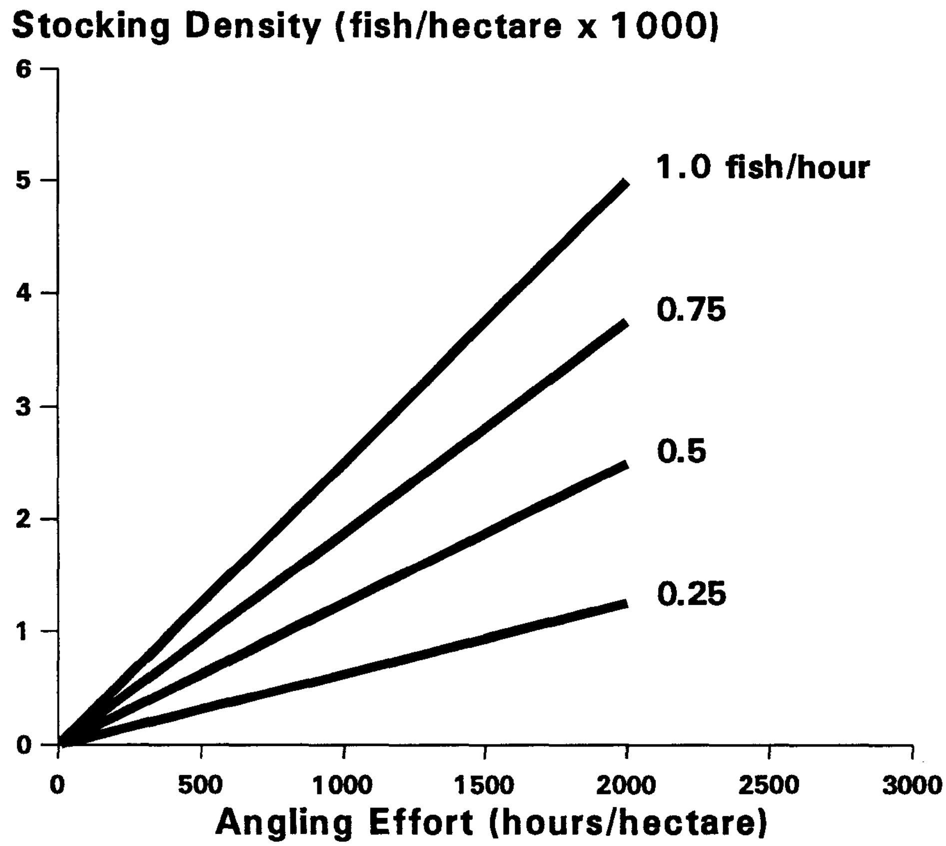

Figure 1. Stocking density for put-and-take trout according to $N = (c/f)f/R$ (Lyons 1964; Kelly 1965) for 40% return-to-creel and several harvest rates.

records are not presently published in annual reports in Idaho. Difficulty obtaining complete, accurate records could limit future hatchery evaluations.

In practice, put-and-take fisheries are seldom assessed (Hartzler 1988; Fortin and McCabe 1990). Program adjustments occur rarely. Changes are often based on angler complaints or budget cutbacks. Inefficient stocking that does not fully meet the need for consumptive angling can result. Fishing quality may suffer because resources that could be serving the needs of anglers elsewhere are wasted.

Based on reported harvest estimates, return-to-creel has ranged from 2-86% for put-and-take programs in Idaho streams. Average harvests of 33% of fish stocked were below the 40% return goal (IDFG 1991). Most (70%) stream segments also fell below the statewide goal, though some return rates were close enough to 40% for practical purposes.

Publicity

Making sure people are aware of fishing opportunity offered by stocking programs is important where good returns of hatchery fish are necessary (Hirsch and Gates 1983). Distribution of brochures with detailed maps could increase use. Stocking publicity could be much more specific and widespread than it has been. Considering the concentration of hatchery trout in the vicinity of stocking sites (Job 2), it may not be sufficient to code reaches of streams as hatchery-supported on a map.

If better returns, more participation, and a satisfied fishing public are desired, we need to make sure people know exactly where hatchery fish can be caught, and consistently provide that opportunity. Publication of detailed information also carries a requirement that fishing quality live up to expectations. Publicity programs also need to be monitored to determine if additional costs are justified by increased returns of hatchery fish.

Considering that angling effort is the primary determinant of harvest, this type of expenditure could be cost-effective. In Idaho, if we spent an additional $0.10 per fish or a total of $56,450 for printing and distribution of detailed brochures at license vendors, an increase in return rates to 40% would lower the cost of fish in the creel to $1.80.

Stocking Rates

Number

Increases in the number of trout stocked will generally increase angler success, or catch rate, expressed as fish/hour (Ratledge and Cornell 1952; Rohrer 1990; Mauser 1992). It follows that decreases in fishing effort will also increase the rate of catch (Ratledge 1966), or more important, that stocking should match effort (Cooper 1959; Hartzler 1988).

Total stocking or stocking density can be determined from the relationship of catch and effort (Lyons 1964; Kelly 1965). The ratio of catch and return rates is useful as a guideline for put-and-take stocking, since:

$$N/f = (c/f)/R \tag{2}$$

According to this relationship stocking should equal effort when catch and return rates are equal.

The percentage of stocked fish harvested tends to decline as stocking rates increase (Kelly 1965; Rohrer 1990; Mauser 1992). Both catch and return rates are important, but for different reasons. Return-to-creel is a measure of the cost of stocking programs; catch rate can be a measure of angler satisfaction as well as success (McMichael and Kaya 1991). Angler success rates are useful goals that must be tempered by cost considerations.

Most investigators have found it necessary to fine-tune stocking levels to provide best possible fishing at least cost. Available fish numbers must be kept at a high level by repeated stocking to insure that a majority of anglers will be able to catch even one fish (Cooper 1959).

Increased stocking tends to produce better fishing, at least initially. Better fishing generally attracts more anglers. As anglers harvest more fish, catch rates decline (Ratledge 1966; Carline et al 1991). Poorer fishing in turn increases pressure to stock more fish. This makes determination of the proper stocking level difficult. Upper limits to the number and size of fish stocked may be necessary to avoid overuse of stocked sites (Cooper 1959). Idaho needs guidelines to avoid arbitrary expansion or curtailment of stocking programs.

Cost alone prevents continual increases in stocking to maintain good fishing. Releasing too many fish at a time can cause fishing quality to fluctuate excessively (Butler and Borgeson 1965). Fishery biologists can stabilize harvest rates by reducing number per release and increasing stocking frequency.

Several authors have used catchability to determine stocking rate (Butler and Borgeson 1965; Pawson 1982; North 1983). Catchability (q) is calculated from the catch rate (c/f) produced by a test release (No) as:

$$q = (c/f)/No. \tag{3}$$

Number to stock (Ns) to achieve a given catch rate (c/fd) is then:

$$Ns = (c/fd)/q \tag{4}$$

the previous release remaining at restocking:

$$Nr = p(c/fd)/q \tag{5}$$

For most put-and-take fisheries restocking when 50% of the previous release remains is adequate to reduce catch rate fluctuations to acceptable levels (Butler and Borgeson 1965).

Catchability of trout stocked in streams is intensely site-specific, which may require estimates for each area. I estimated 240 fish per release should be stocked at sites on the upper Salmon River based on test releases and angler interviews conducted in 1992 (Job 2, Catchability). Site specific stocking should be more accurate than general guidelines. Test releases provide an opportunity to estimate survival and calculate site-specific stocking frequencies.

Estimates of number per release for three sites on the upper Salmon River (Job 2, Catchability) varied considerably over time. Some of the variability could have resulted from inadequate sampling of the fishery and differences between individual anglers. Weather and other fishing conditions may also have contributed to fluctuations in harvest rates, and ultimately, number per release.

General guidelines based on stream length or area might require less data to implement. Some agencies stock put-and-take trout on a stream length (fish/kilometer) or area (fish/hectare) basis.

Most stocking programs have developed over a long history of trial and error. This approach is superior when properly evaluated (Hilborn 1992). A process of refinement should be used to adjust guidelines to specific stocking sites. Since valid assessments require the same levels of effort as the catchability approach, IDFG may have to limit in-depth evaluations to key fisheries. Documentation and analysis should be used to refine and improve basic guidelines.

Frequency

Stocking frequency, or time between releases, depends on how rapidly fish are removed by angling, leave the area or die from causes other than harvest. In an intensive fishery, harvest and hence effort, primarily determine stocking frequency (Pawson 1982). Though stocking periods that will best stabilize angling success will vary with the fishery, restocking when 50% of the previous release remains is probably close to optimum for many put-and-take programs (Butler and Borgeson 1965).

Time between releases can be calculated from ratios of instantaneous mortality (Job 2). Iowa stocked rainbow trout and brown trout Salmo trutta at least once a week in areas with good angler access. Monthly intervals and brown trout alone were used where fishing pressure was lower (Wunder and Stahl 1986). I estimated fish should be stocked about every 2 weeks in sections of the upper Salmon River in 1992 (Job 2, Survival). For Idaho streams in general, 1-3 week intervals should suffice, the shorter intervals for more intense effort. Stocking intervals rather than number stocked should be modified in response to changes in fishing intensity during the fishing season on a body of water (Butler and Borgeson 1965).

Cooper (1959) felt frequent releases of small numbers of fish might have the practical disadvantage of making it difficult to maintain angler interest to fully utilize them. Stocking more often requires more time to distribute fish. Though increasing stocking frequency should stabilize catch rates, additional costs would not be offset by better returns unless effort corresponds to more consistent fishing. Increasing stocking frequency and number of sites had no effect on rate of return at low levels of angling effort (88 h/hectare) in the Middle Fork Boise River (Rohrer 1990).

Fish Distribution

Movement of hatchery trout stocked in streams is important for designing stocking programs. Distance between release sites and number of stocking locations affect allocation of fish to streams or stream segments.

The majority of fish recovered in put-and-take fisheries in streams generally are caught within a few kilometers of release sites (Butler and Borgeson 1965; Casey 1965; Bell 1966; Webb 1969; Cresswell 1981; Chapman 1983). Movement tends to be downstream and vary with rainbow trout strain (Swartz 1950; Eipper 1963; Bricker 1970; Moring 1982).

Kendall and Helfrich (1980) found rainbow trout moved a median distance and direction of 30 m downstream. Anglers caught 75% of the fish within 400 m of release sites. Stocked fish may drift greater distances downstream due to poor health, competition, low temperatures, or high flows (Butler and Borgeson 1965; Bricker 1970). Adams (1960) noted a potentially significant exception to the general pattern in an Idaho stock of rainbow trout which moved upstream in the Truckee River.

Bjornn and Mallet (1964) found 85% of the hatchery rainbow trout caught during the season they were stocked in the upper Salmon River were 1.6 km or less from release sites. In 1992, hatchery rainbow dispersed throughout the 3-4 km stream sections we monitored in the upper Salmon River and Valley Creek (Job 2, Movement). Eighty-percent of the fish we located were within 0.5 km of release sites.

Despite differences in direction and amount of movement in various waters, most Idaho stream fisheries should benefit from spot stocking fish, assuming most will be caught within 1-3 km (Job 2). Spot stocking where fishing pressure is greatest, and limited movement from accessible stocking sites increase harvest rates (Shuck 1948; Butler and Borgeson 1965; Webb 1969). Conversely, stocking fish out of reach of the average angler reduces the fraction recovered (Cooper 1959). Improved angler access increases put-and-take trout harvest in streams.

Catchability

Besides stocking and effort, catchability is important for put-and-take programs. In order for fishing pressure to be effective, fish must be catchable.

Catchability is mainly a function of physical conditions and fish and angler behavior. Catchability tends to be specific and fairly constant for a given water (Pawson 1982), but may decline rapidly as fish are removed in highly intensive, hatchery-supported fisheries (North 1983).

At any given water with a stable stocking program, catchability is primarily dependent on the fish's environment. Site selection is, therefore, an important component. The catchability of fish stocked into a large accessible pool is greater than that of fish dispersed along a mile of stream (Butler and Borgeson 1965). Hatchery personnel exert considerable control over fishing quality by how and where they stock. Site characteristics and other means of increasing catchability are prime areas for additional investigation.

Water Suitability

Catchability tends to decline with increases in the amount, or size of water stocked (Butler and Borgeson 1965). High water, turbidity, stream gradient, food availability, cover, weather, length of stream stocked, and distribution of fish all affect catchability (Butler and Borgeson 1965).

McMichael and Kaya (1991) found catchability varied with water temperature. Rainbow trout feed and are caught most readily at 8-13°C.

Fish Characteristics

Catchability varies with fish health, species, and stock (Schuck 1948; Trojnar and Behnke 1974; Dwyer and Piper 1984; Fay and Pardue 1986; Potter and Barton 1986; Wydoski 1986). The most catchable fish are best for put-and-take fisheries (Wade 1986). Even where angling effort is high enough to harvest most of the fish present, the most catchable fish will be removed first (Cooper 1959).

Hatchery trout are more catchable than their wild counterparts (Cooper 1959). Catchability appears to increase with degree of domestication (Brauhn and Kincaid 1982; Dwyer and Piper 1984; Kincaid and Berry 1986). Species and stock differences have potential to decrease stocking needs, or increase angler success and returns (Cooper 1959).

Selection of easily-caught fish for broodstock might be used to develop highly catchable stocks. Lewensky (1986) found vulnerability to angling varied among individual hatchery trout. In Illinois, biologists developed a more vulnerable strain of largemouth bass by breeding only the most catchable individuals from Ridge lake (David P. Philipp, Illinois Natural History Survey, personal communication).

Fish size is a key factor affecting catchability. For the same weight of hatchery trout stocked, yield increases with fish size (Mullan 1956; Gebhards 1962; Butler and Borgeson 1965; Casey 1969a; Potter and Barton 1986; Mauser 1992). This could be a consideration for hatchery planning since costs of rearing larger fish can be weighed against benefits of increased harvest and return rates. Wiley et al. (1993b) hypothesize cost of trout-to-the-creel declines as size of stocked fish increases. The intrinsic value of large fish is another consideration. Measures of angler satisfaction that can be used to supplement direct cost analysis would be useful.

Finally, fish behavior is an area that investigators have explored to increase yield to the fishery. Most of this work has dealt with increasing survival and performance of hatchery-reared fish by conditioning to food, predators, or physical conditions (Suboski and Templeton 1989; Wiley et al. 1993). Training or conditioning fish to modify their catchability has met with varying degrees of success (Fortmann et al. 1961; Casey 1969b; Webb 1969; Bricker 1970), and additional work to determine potential benefit is likely (Bryan 1972; Bachman 1984).

RECOMMENDATIONS

1. Spot stock where angler use is high or high use is desired. Stocking should match effort where catch and return rate goals are similar. Fish should be stocked every 1-3 weeks at sites every 1-3 km. Stocking intervals should be shortened for higher effort levels and smaller streams.

2. Publicize stocking sites with information specific and widespread enough to allow casual anglers to find them easily. Adjust expenditures for brochures to return rates for best cost:benefit. An additional $0.10 per fish for stream stocking might be a good starting point.

3. Stock small, accessible, fishable areas with large fish to increase catchability. Monitor individual areas to make sure fish **are** not wasted.

4. Stock when weather, angling effort, and water temperature and clarity are optimal for catching most of the hatchery fish shortly after stocking. About 75% of the allocation for Idaho stream fisheries should be stocked prior to August 1 each year unless significant changes in the general pattern of fishing pressure occur.

5. Develop a more catchable stock of fish for put-and-take programs in Idaho. Compare benefits to standard Hayspur stock. Stock larger trout to maximize harvest rates.

6. Fund systematic census to evaluate put-and-take fisheries on a regular basis. Major fisheries may need to be evaluated at least every fifth year, more often if possible. Individual stocking sites should be checked and adjusted based on informal angler counts conducted each year.

7. Publish stocking records in separate annual reports. Unpublished data may not be readily available for future assessments.

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JOB PERFORMANCE REPORT

State of: **Idaho**

Name: **Hatchery Trout Evaluations**

Project: **F-73-R-15**

Title: **Persistence and Dispersion of Put-and-Take Trout in Streams**

Subproject: V

Study: I

Job: 2

Period Covered: **April 1, 1992 to March 31, 1993**

ABSTRACT

In this report segment, I describe results of field experiments concerning persistence and dispersal of put-and-take trout in Idaho streams. This information is important to determine both how often and far apart to stock hatchery fish.

Stocking intervals should be about 1-3 weeks, with the shorter intervals for greater angling effort. Some knowledge of the distribution and intensity of angling effort (hours/hectare/year) is necessary to optimize temporal distribution of annual allocations (fish/hectare/year). In most cases, intervals should be set so at least 75% of the season total is stocked prior to August 1.

Stocking sites should be separated by 1-3 km where an entire stream reach is managed for intensive harvest of put-and-take trout. The same distances should be used to calculate stocking densities for spot stocking. Distances may need to be increased for large rivers and decreased for small streams.

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INTRODUCTION

One of the key components needed to adjust stocking schedules is some knowledge of how many fish remain alive and available for harvest after stocking. Most investigators have found fish stocked in flowing water move little and disappear rapidly (Cresswell 1981). In Idaho, Bjornn and Mallet (1964) found 85% of hatchery rainbow trout Oncorhynchus mykiss stocked in June and recovered by anglers the same summer were within 1.6 km of stocking sites on the upper Salmon River. Chapman (1983) reported most anglers fishing the North Fork Payette River recovered hatchery rainbow trout short distances from stocking sites. Adams (1960) found hatchery-reared fish of an Idaho stock behaved differently than the norm. We sought to compare movement of hatchery fish in Idaho streams to other put-and-take studies.

Most workers have found relatively short periods of time before a large percentage of the eventual harvest is taken by anglers in a put-and-take fishery. Hayes (1990) reported rainbow trout abundance was too low to produce desirable catch rates within 1.5 months of stocking. Chapman (1983) reported mean time to harvest of 31 d with more than 50% of the total harvest taken in 21 d. Recent census and tagging work, however, led us to question whether fish were surviving and contributing for longer periods of time in some Idaho streams (Heimer 1980; Rohrer 1990; Mauser 1992) than commonly reported. We wondered if longer harvest intervals were related to lower levels of fishing intensity.

To find out if fish in Idaho streams were performing as indicated by existing reports, we assessed persistence and dispersion of hatchery rainbow trout in 1992. This report covers work on the Upper Salmon River in south-central Idaho. Similar work was conducted by Davis (1994) on the Coeur d'Alene River in northern Idaho.

OBJECTIVES

1. Evaluate survival, dispersal, and catchability to determine reasons for poor returns of put-and-take trout in streams.

METHODS

Field Sampling

We selected two stream sections on the Salmon River and one section on Valley Creek for monitoring persistence and dispersion of stocked rainbow trout (Figure 1). We based each section on a site normally stocked in the put-and-take program. We chose study areas separated by distances we believed adequate to minimize movement of marked fish into adjacent sections.

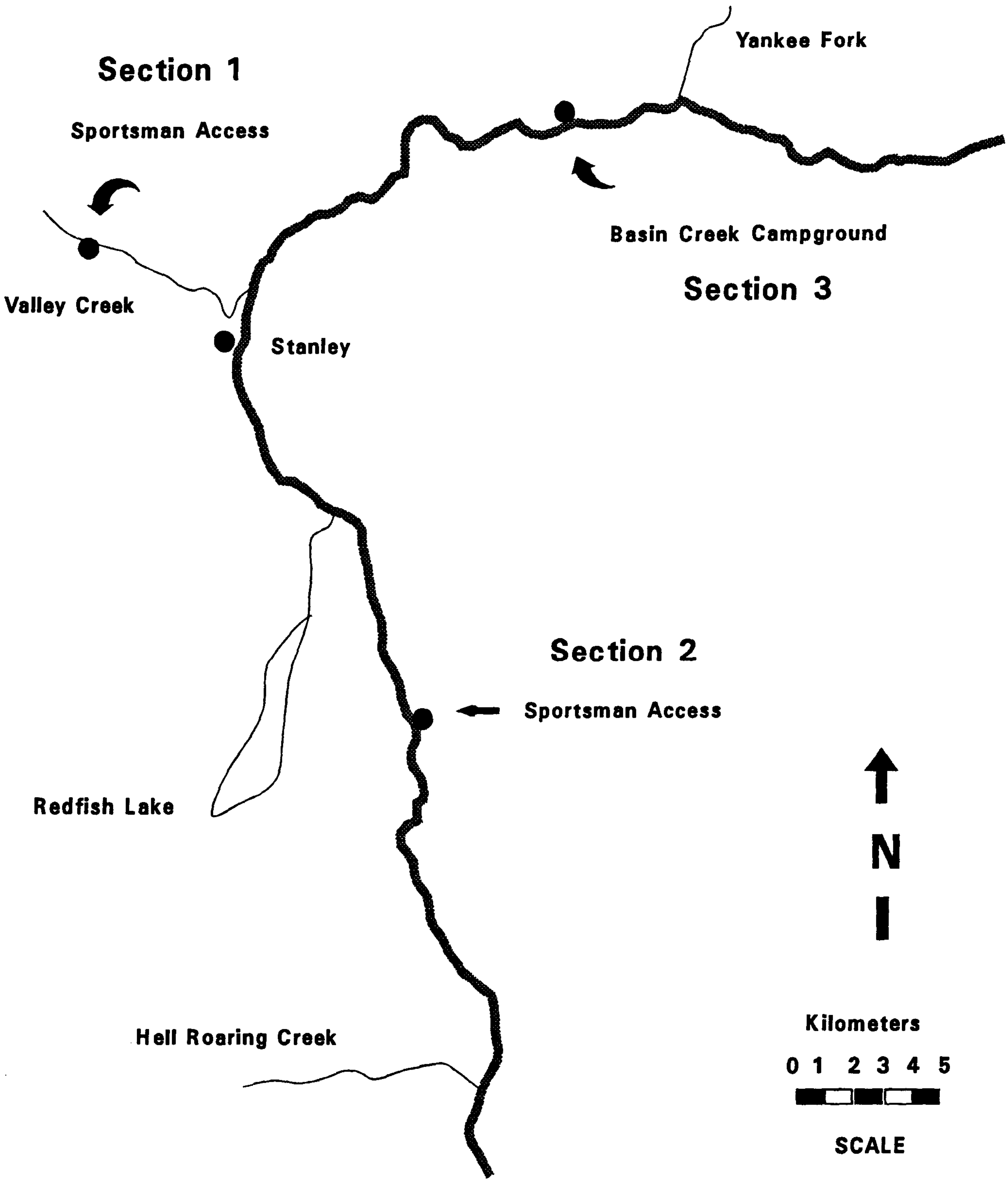

Figure 1. Map of the upper Salmon River showing sites monitored with marked hatchery trout in 1992.

Sawtooth Fish Hatchery personnel stocked marked fish four times at each site between June 11 and August 7, 1992 (Table 1). Initially we stocked about 215 fish per site. This was an approximate number released into area streams. We subsequently stocked 500 fish per release into Salmon River sections because we felt snorkel counts were too low at initial stocking levels. We used colored plastic clothing (Floy-type) tags to identify release groups. We tagged fish at Sawtooth Fish Hatchery about 10 d before stocking and placed them in empty raceways for recovery. During July we placed one group of tagged fish in a transport truck before returning them to a separate raceway. These fish showed no noticeable tag loss or "post-stocking" mortality through August 21.

Depending on stream size, one or two observers counted fish in snorkel transects. Usually one person counted transects in Valley Creek. In the Salmon River, one observer counted fish between the other snorkeler and the adjacent shore, the other counted only toward the opposite shore. Snorkelers stopped periodically to maintain contact with each other, record information, and check distances against shore markers. We made no attempt to count all fish present, only to count transects as consistently as possible each time.

We divided each section into segments to facilitate location of fish in relation to point of release. We marked stream segments with bright orange surveyors tape tied to riparian vegetation. We started with a system of unequal increments on the assumption that fish would disperse short distances, primarily downstream.

We designated stocking sites as 0 m. We marked off a single 250 m segment upstream of each stocking site. Downstream, we utilized 25 m increments for the first 500 m, 50 m increments from 500 to 750 m, and 125 m increments from 750 to 1000 m. We modified these segments as necessary to encompass observed movement patterns of marked trout.

Section 1 - Valley Creek at Elk Meadows

The Valley Creek site was located at the sportsman access immediately below the Elk Meadows R.V. Park 4.8 km west of Stanley on Highway 21 (Figure 1).

We snorkeled Section 1 from 250 m upstream to 1,000 m downstream from June 12 to June 22. On June 26 we extended the transect to 1,000 m upstream and 2,000 m downstream in 100 m increments. We floated this 3 km until August 7 when we concluded counts due to low water.

Section 2 - Salmon River at Rembers

The stocking site was located at the sportsman access 2.4 km upstream of Sawtooth Fish Hatchery on Highway 75 south of Stanley (Figure 1).

On June 11, we counted from 250 m upstream to 1,000 m downstream. On June 24 we extended the transect to 2,000 m downstream in 100 m increments.

Table 1. Number of marked hatchery rainbow trout stocked at three locations in the upper Salmon River drainage in 1992.

Tag Group	Stocking Date	Release Site: Valley Creek	Release Site: Rembers	Release Site: Basin Creek	Totals
1	May 11-12	220	215	215	650
2	July 8	215	500	0	715
3	July 23	200	500	500	1200
4	August 16-17	200	500	500	1200
Total	May 11-August 17	835	1715	1215	3765

After July 14, we no longer drifted the last 1 km downstream because we had counted no marked fish there.

Beginning July 16, we moved the starting point to 2,000 m upstream in 100 m increments. We floated this 3 km until the conclusion of counts August 14.

Section 3 - Salmon River at Basin Creek

Section 3 extended from approximately 1,100 m upstream of the Basin Creek Campground to 1,000 m below the hot springs. The hot springs were located approximately 1 km downstream of Basin Creek Campground on Highway 75 east of Stanley (Figure 1).

We floated Section 3 from 250 m upstream to 1,000 m downstream June 12-June 23. We did not count from June 23 to July 23 due to limited visibility and high water.

On July 24, we extended the starting point to 2,000 m upstream in 100 m increments. We counted this 3 km until August 14.

Stocking Calculations

Number to Stock

I used angler interview data to estimate number of fish to stock based on the releases we made. I calculated number per release to obtain a given catch rate assuming a proportional change in angler success with stocking (Butler and Borgeson 1965). We interviewed anglers in each section to obtain information on marked fish caught and hours fished. I calculated catchability (g) for each release group and stream section from the harvest rate (c/f) from angler interviews, and the number of hatchery trout we released (No).

$$g = (c/f)/No \tag{1}$$

I estimated the number of fish to release each time (Nr) from the proportion of the previous release remaining at restocking (p), catchability (g), and the catch rate desired (c/fd).

$$Nr = p(c/fd)/g \tag{2}$$

Stocking Frequency

I estimated survival of stocked fish to calculate stocking frequency. I used mark-recapture ratios of different groups of fish to make periodic abundance estimates. I estimated the number of fish alive after time t (Nt) from the number stocked in **a** subsequent release ($\underline{M}$), the snorkel count of both groups (C), and the count of the subsequent group only (R) (Hepworth et al. 1991).

$$\underline{Nt} = (\underline{MC}/\underline{R})-\underline{M} \qquad (3)$$

I estimated weekly instantaneous mortality (Z) for each tag group from regressions of the natural log of abundance against time in weeks. I calculated time between releases in weeks or days from:

$$\underline{t} = \underline{Zt}/\underline{Z} \qquad (4)$$

where $\underline{Zt}$ = -natural log($\underline{p}$), and $\underline{p}$ = 0.5, the desired proportion of the previous release remaining before the next release (Butler and Borgeson 1965; Pawson 1982).

RESULTS

Total counts for any release of hatchery fish we monitored never approached numbers stocked (Figures 2-5). This was true even when we counted within days, even hours, of stocking.

Fish dispersed to the 3-4 km we monitored (Table 2). The first few days after stocking, we found most fish short distances from release points. Fish dispersed upstream and downstream thereafter. Distances (Table 2) must be doubled to approximate dispersal, or movement in both directions.

Mean distance from release sites was 355 m for all groups stocked at all locations (710 m dispersal). Maximum dispersal within the stream lengths we monitored was 3.8 km. Maximum movement in one direction was 2 km (Table 2). We found most (80%) of the fish within 0.5 km of release points, with virtually all (97%) within 1.5 km (1-3 km total dispersal). See Appendices A-C for the extent of movement in individual sections.

Movement was primarily upstream in Salmon River sections (Figures 3-5). In Valley Creek, shallow water immediately upstream of the release site may have limited upstream movement (Figure 2).

Hatchery rainbow trout remained in stream sections at low densities throughout the summer (Figures 2-5). Weekly instantaneous mortality rates ($\underline{Z}$) were 0.32-1.34 (Figures 6-8). At each site, the May release (Group 1) appeared to survive longer than subsequent groups.

Catchability estimates ranged from 0.00038-0.00289 and were quite variable, bearing little relationship to stocking rate within individual sections, except perhaps in Valley Creek (Table 3). Overall estimates were fairly consistent for catchability and number per release (Table 3).

Estimated number to stock to reach **a** harvest rate of 0.5 fish/h, with 50% of a previous release remaining, varied from approximately 90-670 fish with a mean of 241 fish per release (Table 3).

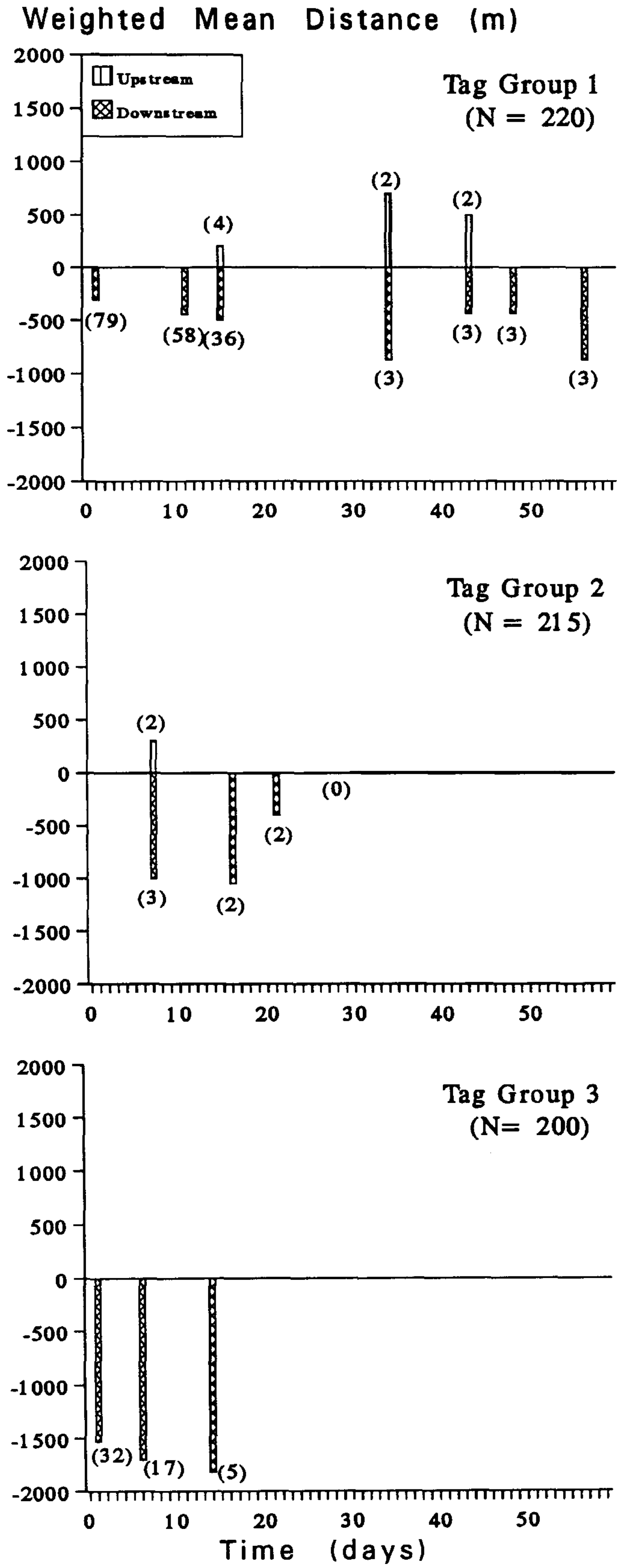

Figure 2. Number of fish ( ), distance from stocking site, and time after stocking for hatchery rainbow trout observed in underwater transects in Valley Creek at Elk Meadows west of Stanley, Idaho.

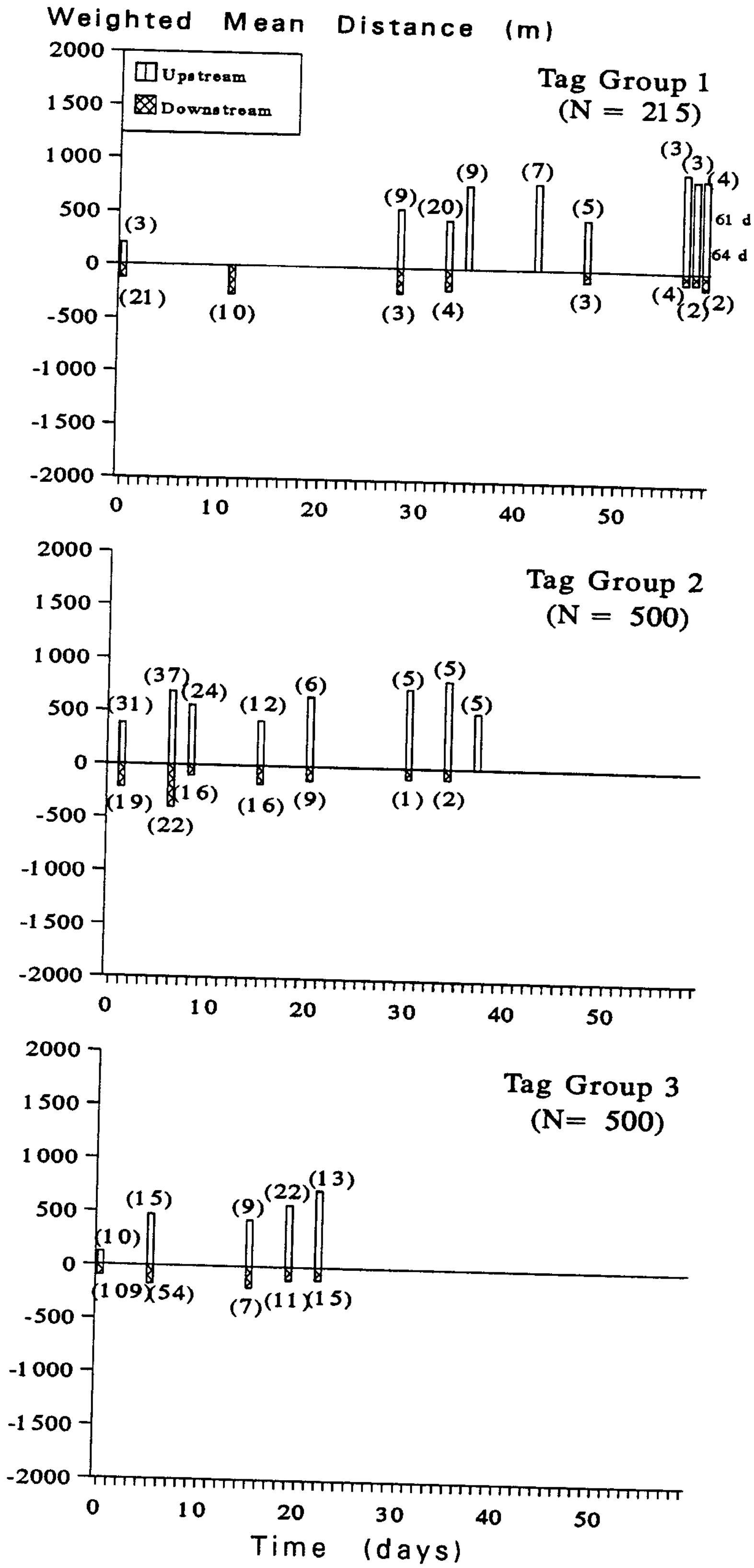

Figure 3. Number of fish ( ), distance from stocking site, and time after stocking for hatchery rainbow trout observed in underwater transects in the Salmon River at Rembers access upstream of Stanley, Idaho.

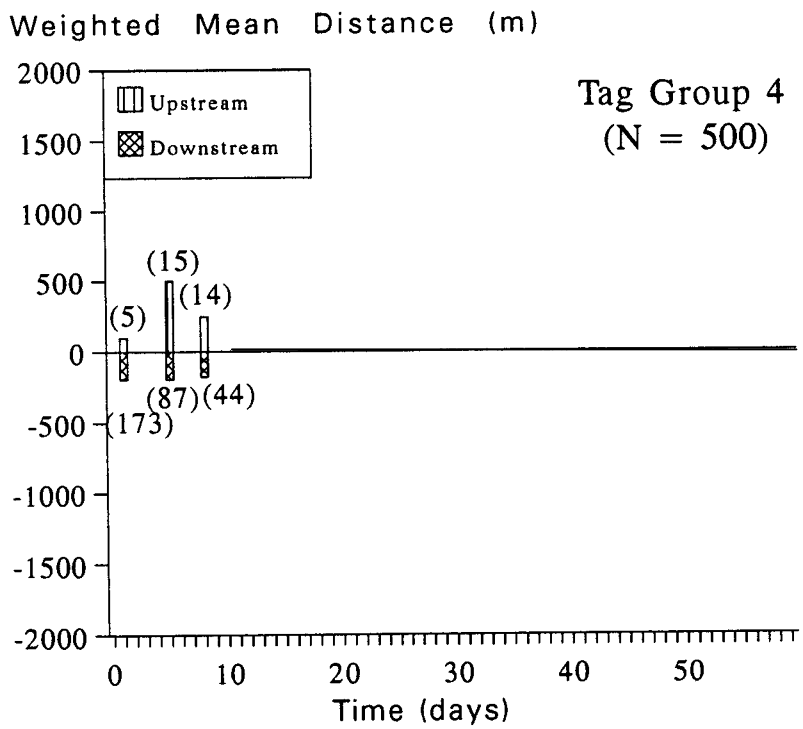

Figure 4. Number of fish ( ), distance from stocking site, and time after stocking for hatchery rainbow trout observed in underwater transects in the Salmon River at Rembers access upstream of Stanley, Idaho.

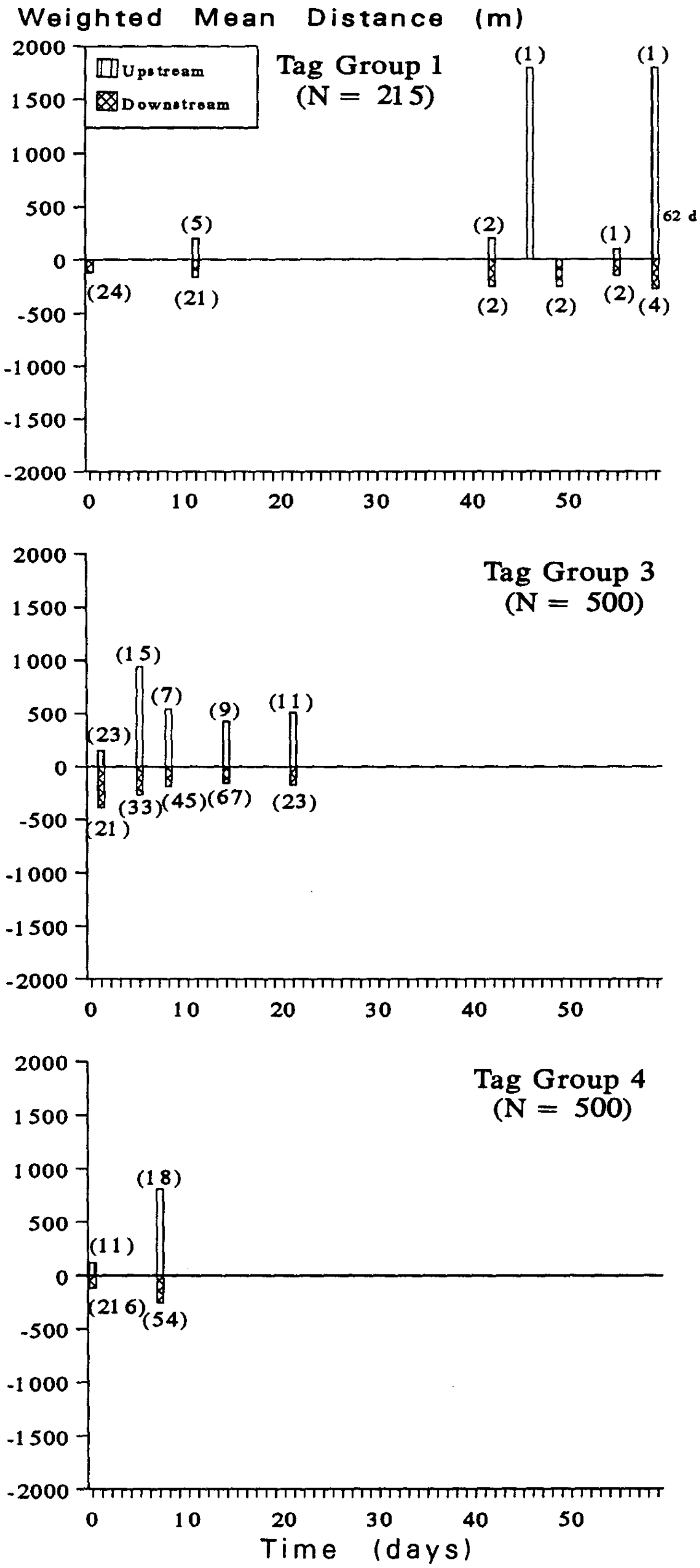

Figure 5. Number of fish ( ), distance from stocking site, and time after stocking for hatchery rainbow trout in underwater transects in the Salmon River near Basin Creek Campground downstream of Stanley, Idaho.

Table 2. Movement of hatchery rainbow trout in the upper Salmon River and Valley Creek in 1992.

Tag Group	Number of Observations	Distance (m) from Release		Cumulative % at Various Distances (m)											
		Mean	Max	100	200	300	400	500	600	700	800	900	1,000	1,500	2,000
1	370	394	1,900	33	45	57	69	78	80	81	83	94	98	99	100
2	221	416	1,800	36	43	60	67	69	70	74	82	93	99	99	100
3	525	417	2,000	51	66	70	75	79	79	82	85	88	89	93	100
4	514	236	1,800	48	83	87	88	89	90	90	97	98	99	100	100
Total	1,630	355	2,000	44	63	71	77	80	82	83	88	93	96	97	100

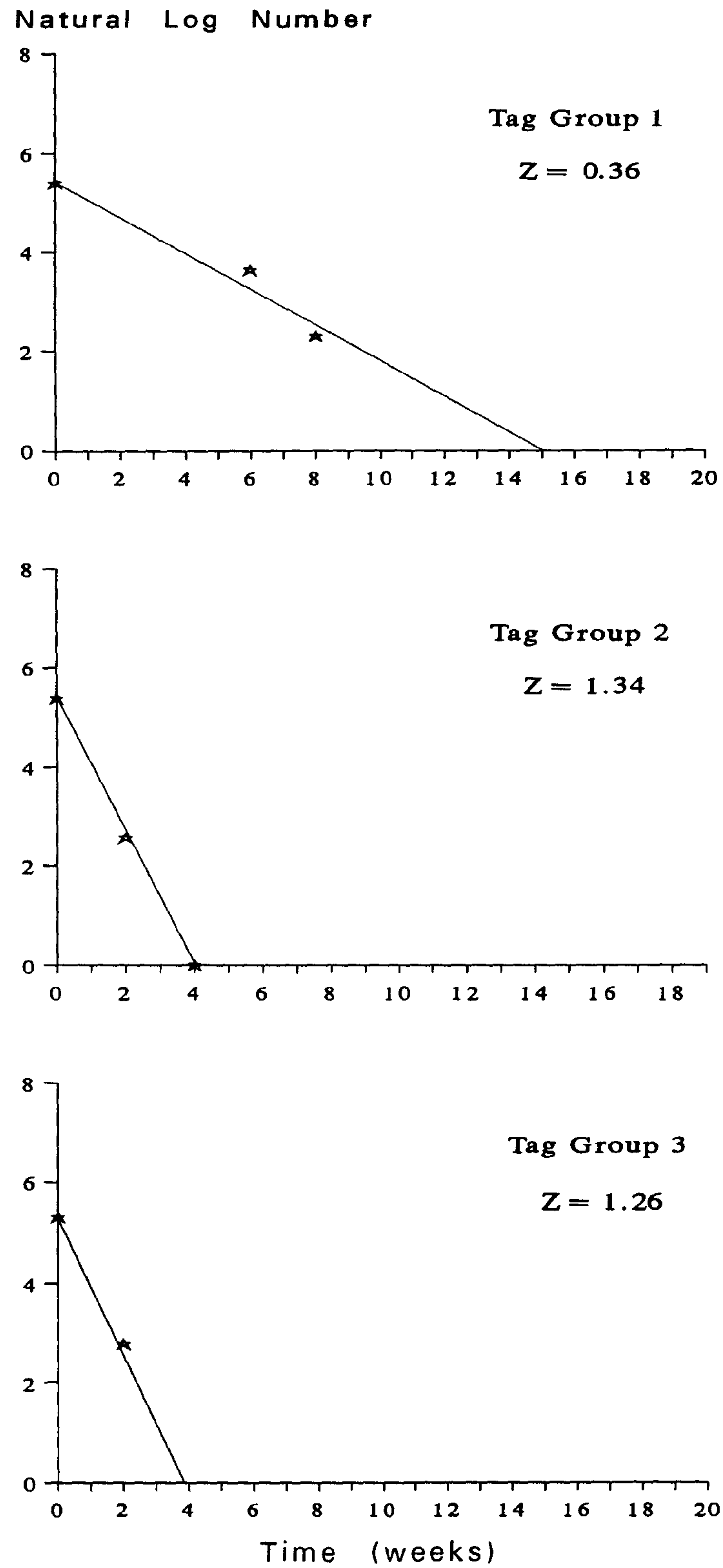

Figure 6. Estimates of weekly instantaneous mortality for hatchery rainbow trout stocked in Valley Creek at Elk Meadows west of Stanley, Idaho.

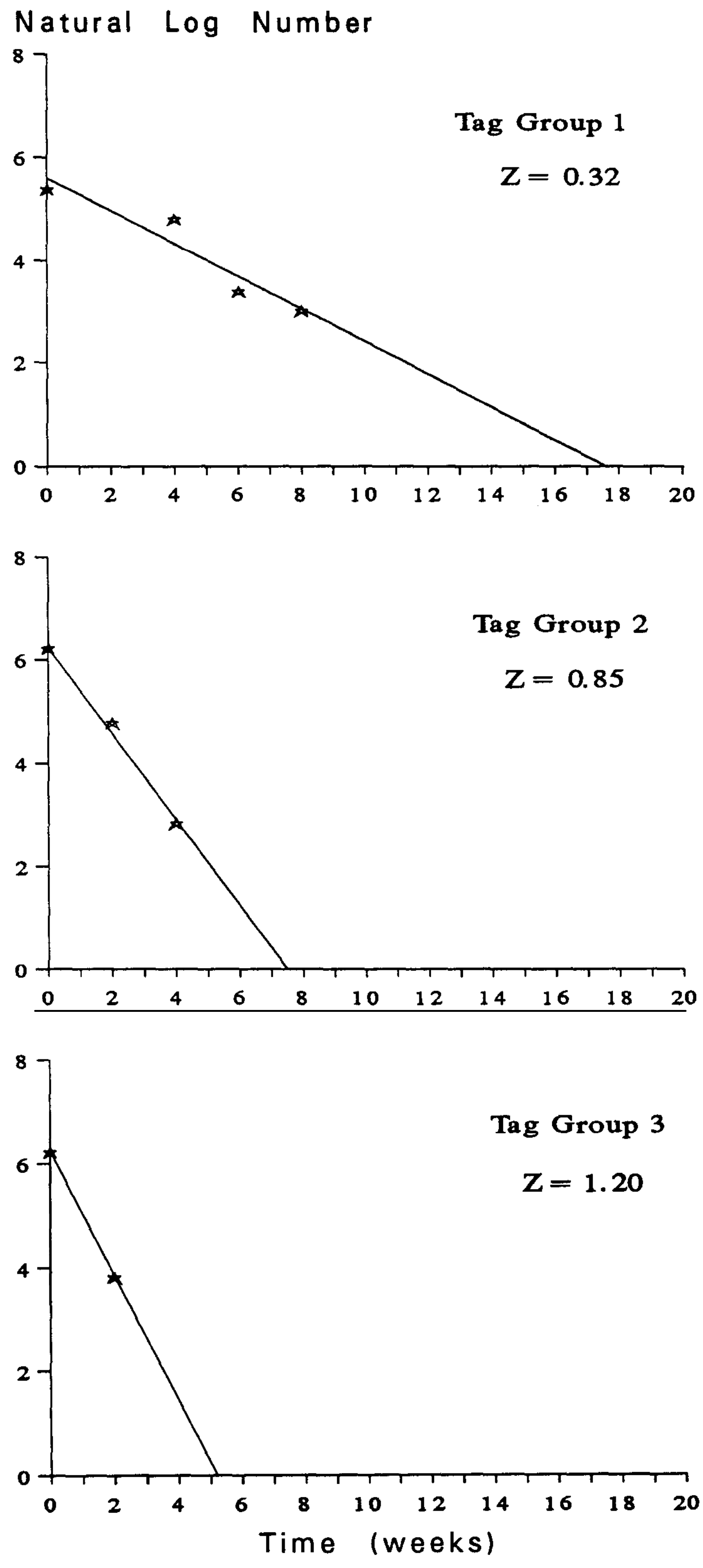

Figure 7. Estimates of weekly instantaneous mortality for hatchery rainbow trout stocked in the Salmon River at Rembers access upstream of Stanley, Idaho.

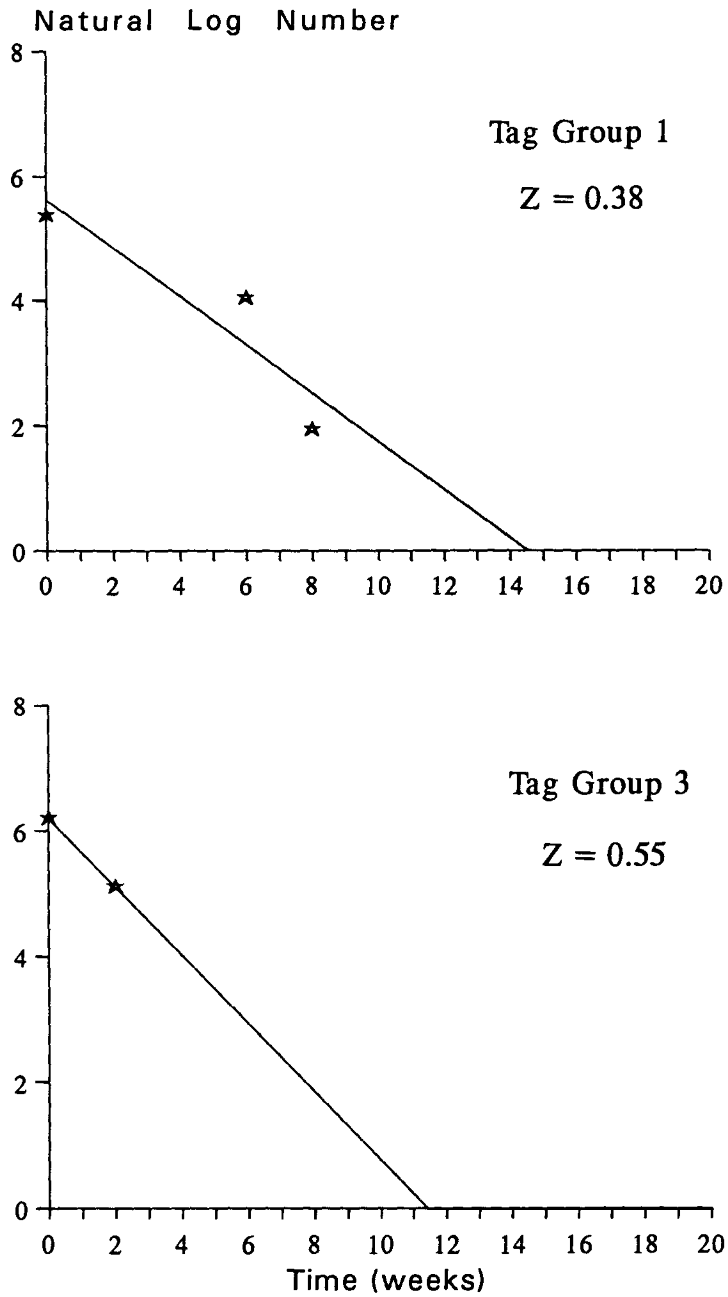

Figure 8. Estimates of weekly instantaneous mortality for hatchery rainbow trout stocked in the Salmon River at Basin Creek Campground downstream of Stanley, Idaho.

Table 3. Catchability and stocking rate estimates for Valley Creek and the upper Salmon River in 1992. Number per release Nr = pr(c/fd)/q. The proportion remaining from a prior release pr = 50% (Butler and Borgeson 1965). Target harvest rate c/fd = 0.5 fish/h.

Tag Group	Angler Interviews	Catch	Hours Fished	Catch Rate	Number Stocked	Catch-ability	Number to Stock
				Valley Creek			
1	10	6	29	0.21	220	9.40E-04	266
2	18	11	47.5	0.23	215	1.08E-03	232
3	21	10	66.5	0.15	200	7.52E-04	333
4	5	6	37.5	0.16	200	8.00E-04	313
Total	54	33	180.5	0.18	209	8.76E-04	285
				Rembers Access			
1	23	13	50.25	0.26	215	1.20E-03	208
2	35	46	85.75	0.54	500	1.07E-03	233
3	18	38	44.5	0.85	500	1.71E-03	146
4	4	5	18.5	0.27	500	5.41E-04	463
Total	80	102	199	0.51	429	1.20E-03	209
				Basin Creek			
1	8	9	14.5	0.62	215	2.89E-03	87
3	58	27	144	0.19	500	3.75E-04	667
4	37	55	97.5	0.56	500	1.13E-03	222
Total	103	91	256	0.36	405	8.78E-04	285
Grand Totals	237	226	635.5	0.36	342	1.04E-03	241

Estimated time between releases with 50% remaining was 4-15 d depending on weekly instantaneous mortality (Table 4). Intervals were longer for fish stocked early in the season. The mean estimate of interval length for all areas was 13 d.

DISCUSSION

Extent of movement was similar to that reported in other investigations, but less than Bjornn and Mallet (1964) found from angler returns on the upper Salmon River in 1961. The amount of upstream movement surprised us. Davis (1994) located Hayspur rainbow trout as far as 8 km upstream of stocking sites on the Coeur d'Alene River. To improve catchability we may wish to use a stock that moves less (Moring 1982).

We may have increased movement of hatchery fish when we more than doubled stocking densities in Salmon River sections to improve count data. Larger groups of hatchery trout may move longer distances and disperse sooner after stocking than smaller numbers (Jenkins 1971). If this occurred, we did not detect it. Due to limitations of our design, we interpret our results with caution.

Some of the stocking interval estimates for the upper Salmon River and Valley Creek in 1992 were surprisingly short (less than a week). In 1991, angling intensity on the upper Salmon River averaged only 165 hours/hectare (Mauser 1992). Peaks in effort may result in short interval estimates. Considering practical aspects of fish distribution, variability of effort and catch rate data, I recommend intervals of 1-3 weeks for put-and-take stocking in Idaho streams. The shorter intervals should be used for streams with greater effort, and for peaks in fishing activity.

Dispersal we accounted for led me to recommend stocking distance intervals of 3 km or less. Nbw York used stocking intervals of about 3 km for streams 12 m wide. Stocked sections should be shorter for small streams and longer for large rivers (Engstrom-Heg 1990). As we intensify programs to increase their efficiency, fish may have to be stocked more often at fewer sites.

Like other investigators, we were unable to determine the location or fate of most stocked fish. Though it is unlikely all the missing fish dispersed beyond our study sections, occasional angler returns indicated individual fish may have moved 10 or more km. In 1961, anglers caught hatchery rainbow trout up to 32 km from point of release (Bjornn and Mallet 1964). Additional work will be necessary if we need to know what happens to fish that we cannot account for with existing methods.

Considering the effort already expended trying to learn the fate of stocked trout, time may be better spent improving put-and-take management programs using parameters that have been estimated with more success. We can use existing knowledge to refine stocking schedules in areas where returns are marginal. Areas where returns are prohibitively low may be better suited to something other than put-and-take management.

Table 4. Estimated time (days) between releases t = Zt/Z (Pawson 1982). Zt = -1n (0.5) for 50% survival between releases. Z = weekly instantaneous mortality for hatchery rainbow trout in the upper Salmon River and Valley Creek in 1992.

Tag Group	Zt	Z	t (weeks)	t (days)
		Valley Creek		
1	0.693	0.365	1.90	13
2	0.693	1.34	0.52	4
3	0.693	1.26	0.55	4
Total	0.693	0.38	1.82	13
		Rembers Access		
1	0.693	0.32	2.17	15
2	0.693	0.85	0.82	6
3	0.693	1.2	0.58	4
Total	0.693	0.38	1.82	13
		Basin Creek		
1	0.693	0.38	1.82	13
3	0.693	0.55	1.26	9
Total	0.693	0.42	1.65	12
Grand Totals	0.693	0.37	1.90	13

Catchability may be a useful index of suitability for put-and-take fishing. Because of variability in spot checks of angler success, we may have to develop specific guidelines to ensure reliable estimates. Our results were likely affected by limited angler interviews. Defining waters based on catchability may be worthwhile if data requirements can be met.

Anglers probably harvested many of the fish in our study areas. Effort and harvest levels increased throughout the previous season (1991), as did catch rates (Mauser 1992). We did not conduct angler counts adequate to make effort and harvest expansions in 1992.

Fluctuations in angling effort complicate fish stocking. Many authors have noted patterns in the distribution of fishing effort over time. Thorn (1991) reported 75% of the annual effort occurred before July 1 on Minnesota streams. Smith (1991) found consistency in year-to-year distribution of effort on the Snake River below American Falls.

We may be able to use effort patterns to develop predictive models for how often to stock (Hoenig and Heywood 1991). Stocking frequency, or total allocation, could be based on cumulative effort as well as on density. I summed available effort estimates for a number of Idaho stream fisheries (Appendices D-F). Cumulative effort was consistent, especially within geographical areas of the State. In nearly all cases close to 75% of total effort occurred by early August. Late summer stocking in particular should be closely evaluated to make sure fish are not wasted.

Our results amplify some of the limitations of stream stocking programs. Most important, like other investigators, we felt many of the fish in a given release quickly became unavailable to fishermen. If better utilization is desired, hatchery trout must be stocked where more remain accessible to fishermen.

Anglers appeared to concentrate their efforts where densities of fish we could account for were highest. They did not seem to fish as much in areas hatchery trout dispersed into. We observed most anglers in the immediate vicinity of road access where hatchery fish were stocked. We also found more hatchery trout at or near points of release than in other areas.

Distribution of fishermen in relation to stocked trout may already be optimum for maximum harvest considering the limitations of streams for put-and-take trout fishing. If not, it might be worthwhile educating anglers to bring the two together more often. Stocking trout where they cannot disperse is another option.

Where maximum harvest of put-and-take fish is desired, construction of fishing ponds adjacent to streams may be a way to increase harvest rates. This would allow management of stream habitat for wild stocks while providing good consumptive fisheries in the immediate area.

RECOMMENDATIONS

1. Use 1-3 km per site to calculate stocking area. Modify as necessary to accommodate greater dispersion in larger streams.

2. Stock fish at intervals of 1-3 weeks. Use known or suspected distribution of angling effort to fine-tune stocking frequency (Appendices D-F).

3. Explore the use of catchability indices to allocate hatchery trout in put-and-take management programs.

4. Utilize pond fisheries as alternatives to low returns of hatchery-reared fish in streams.

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Mike Larkin, Tom Rogers, Rick Alsager, and Walt Rast graciously modified hatchery operations to accommodate experimental work. Barbara Heller, Cliff Hawkins, and Lisa Hawkins setup transects, conducted snorkel counts, and with employees at Sawtooth Fish Hatchery, marked fish prior to release. I would especially like to thank Bill Stutz and Bill Nixon for their help at Sawtooth Fish Hatchery.

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APPENDICES

Appendix A. Movement of marked hatchery rainbow trout stocked in Valley Creek in 1992.

Tag	Number of	Distance (m) from Release		Cumulative % at Various Distances (m)											
		Mean	Max	100	200	300	400	500	600	700	800	900	1,000	1,500	2,000
1	193	409	1,900	21	29	46	68	82	86	86	87	95	98	99	100
2	9	722	1.800	0	11	22	56	56	56	56	56	78	78	89	100
3	54	1,609	2,000	0	0	0	4	4	4	4	4	22	28	33	100
Total	63	690	2,000	16	22	36	54	65	67	67	68	79	82	85	100

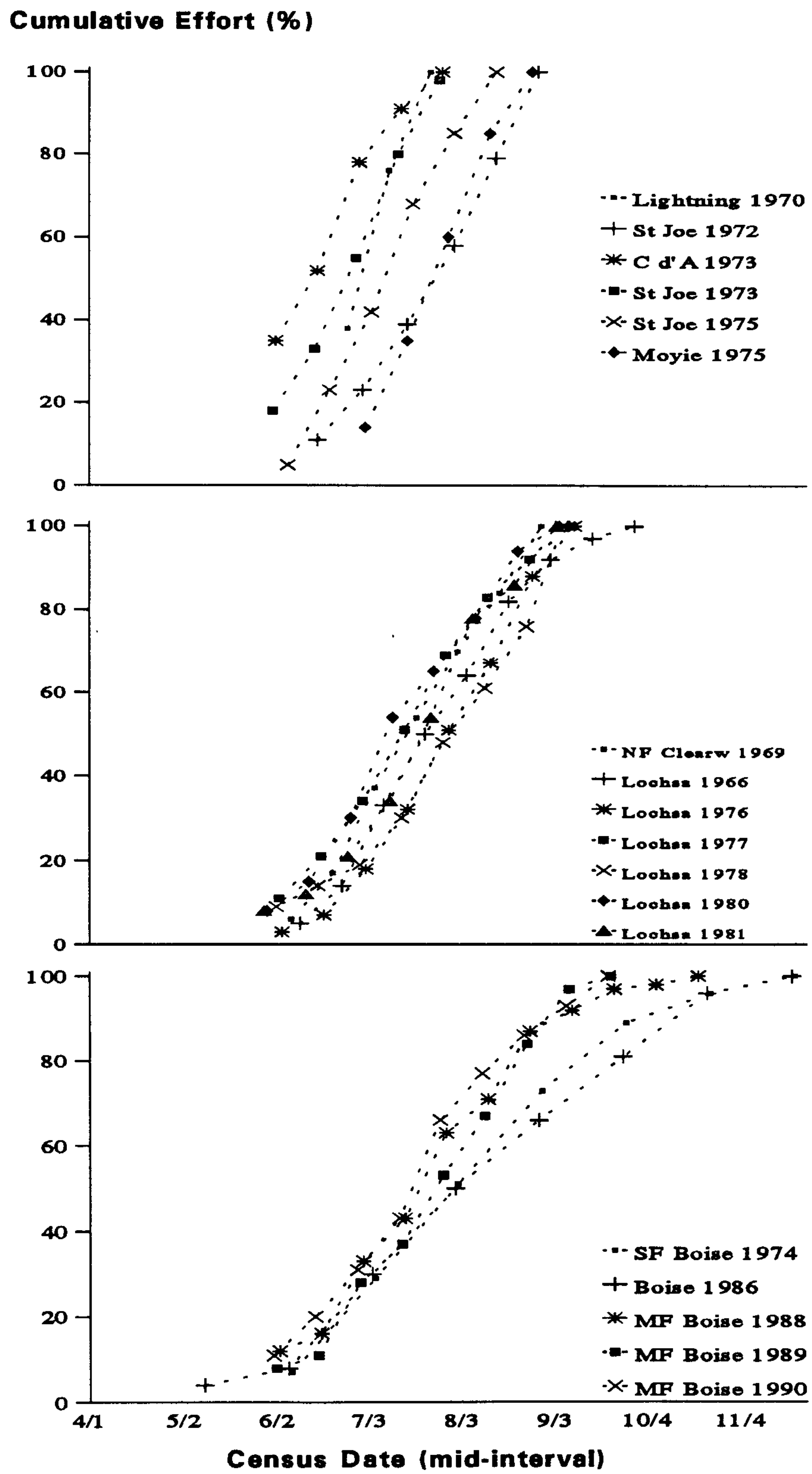
Appendix B. Movement of marked hatchery rainbow trout stocked in the upper Salmon River at Rembers access in 1992.

		Distance (m) from Release		Cumulative % at Various Distances (m)												
Tag Group	Number of Observations	Mean	Max	100	200	300	400	500	600	700	800	900	1,000	1,500	2,000
1	112	340	1,000	39	48	54	56	60	61	63	69	91	100	100	100
2	212	400	1,700	38	44	62	68	69	71	75	83	94	99	99	100
3	217	97	1,100	61	74	82	82	82	83	89	96	100	100	100	100
4	301	97	900	34	85	87	87	87	88	88	99	100	100	100	100
Total	842	315	1,700	42	67	75	77	78	79	82	90	97	100	100	100

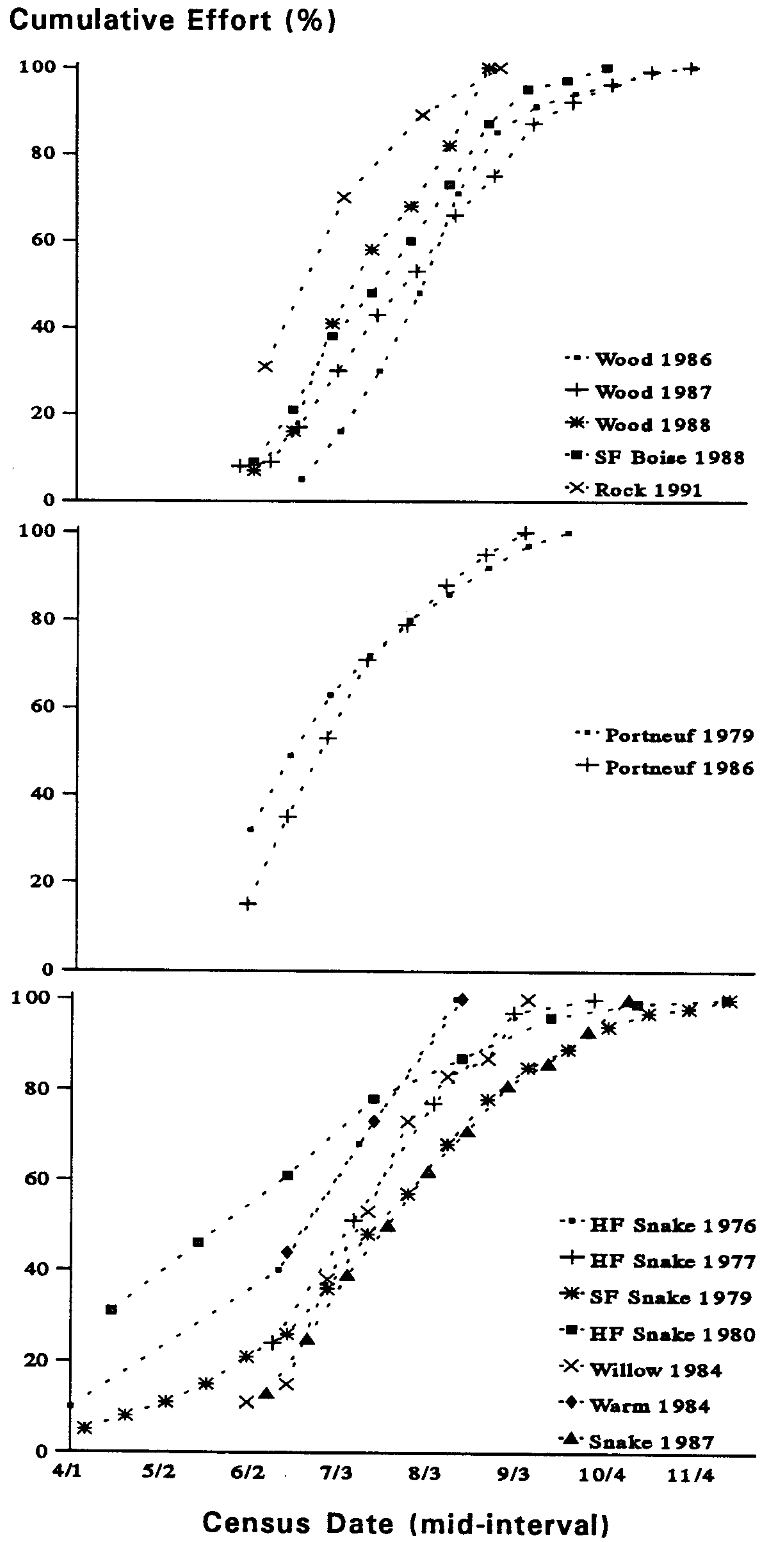
Appendix C. Movement of marked hatchery rainbow trout stocked in the upper Salmon River at Basin Creek Campground in 1992.

		Distance (m) from Release		Cumulative % at Various Distances (m)											
Tag Group	Number of Observations	Mean	Max	100	200	300	400	500	600	700	800	900	1,000	1,500	2,000
1	65	212	1,800	59	85	92	94	85	97	97	97	97	97	97	100
3	254	278	1,800	53	73	75	84	92	92	93	93	93	94	99	100
4	213	217	1,800	68	80	87	90	92	94	94	94	94	97	99	100
Total	532	203	1,800	59	77	82	88	92	93	94	94	94	95	99	100

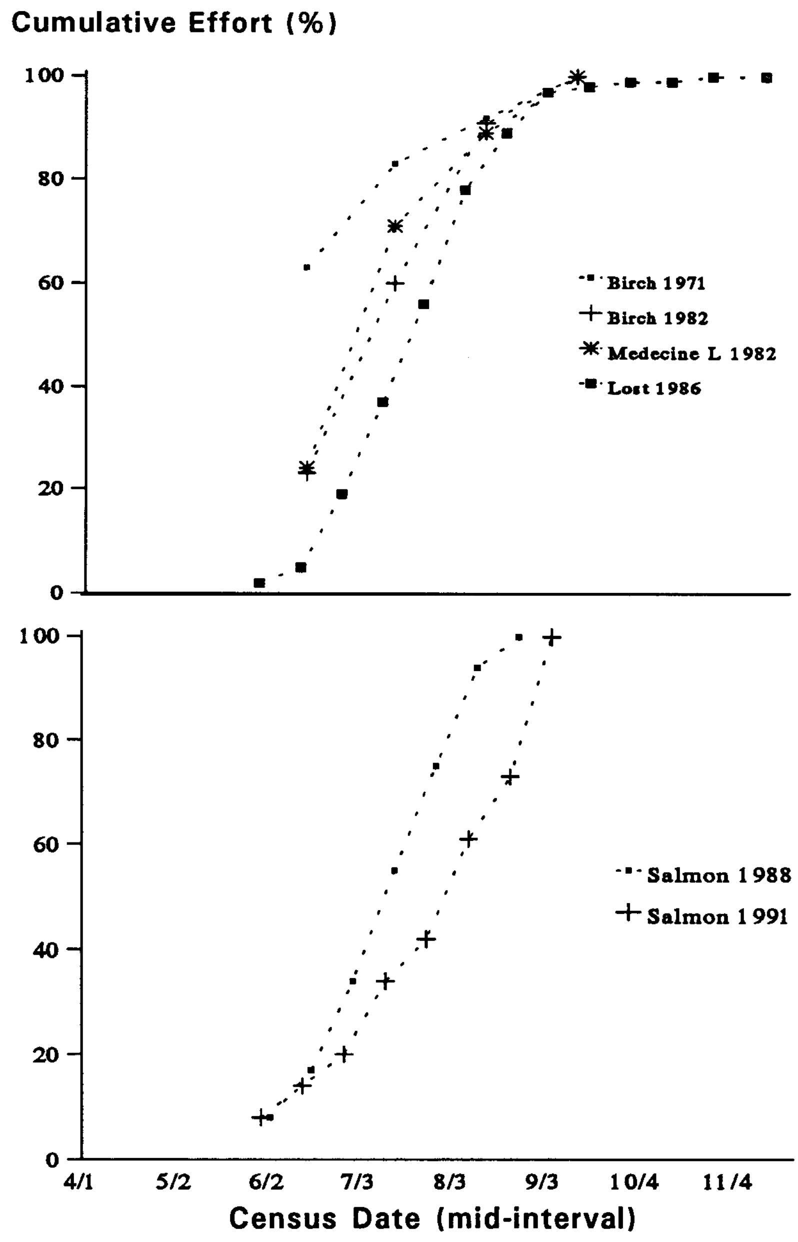
Appendix D. Temporal distribution of cumulative angling effort (hours) for streams in north, north-central, and southwestern Idaho.



Appendix E. Temporal distribution of cumulative angling effort (hours) for streams in south-central and eastern Idaho.



Appendix F. Temporal distribution of cumulative angling effort (hours) for streams in east-central Idaho.



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